Some Keys to Excellence in Neutron Probe Calibration

1) Make sure there is a wide spread in the water content data by finding or creating (eg. by growing a crop of sunflowers) a dry site, and then creating a wet site adjacent to it by berming an area and flooding it until the profile is wetted to the depth desired. Let drain to 'field capacity'.

2) Ensure adequate numbers of samples by installing at least three access tubes in both the wet and the dry sites, and by taking four samples around each tube at each depth that is read with the neutron probe. This typically gives enough samples that calibration equations can be broken out by soil layers or horizons and the slopes can be shown (reliably) to be equivalent or not between layers. (The 10 cm depth always requires a separate calibration equation due to loss of neutrons to the atmosphere.)

3) Ensure that samples are good ones. We do this by trenching alongside the access tubes and sampling horizontally around the tube with a Madera probe. This probe has a small cross sectional cutting area and compresses samples very little. Also, after driving in the probe one can see easily if the sample is compressed, by comparing the soil surface inside and outside the probe body. Likewise, one can see if the sample is shattered, which would result in bulk density being too low for that sample. Bad samples can be discarded on the spot and replacement ones taken. Because this probe gives a 60 cm^3 sample volume, the volumetric water content can be determined directly and the heterogeneity of bulk density and water content assessed at each depth. With four samples per depth per tube, outliers can be discarded later if prudent and there will still be enough samples to give a good mean water content at each depth and tube.

Note that the Madera probe was developed by the SCS in the US for sampling downhole as access tubes were installed. Having used the probe extensively in this way I have concluded that the downhole method is less desirable for two reasons. First, only one sample per depth is obtained. Second, despite the best care samples may be compressed and there is no way to directly assess this with a downhole sample.

4) Ensure that the probe is at the correct depth for each reading. We take readings at 10-cm depth and in 20-cm increments below that. We have built stands that slide over the access tubes and keep the gauges a constant height above the soil surface (in our case 81.5 cm from gauge base to soil surface). We then set cable stops to give the desired depths of measurement. With this system we always get reading depths referenced to the soil surface, not to the top of the access tube. In normal field use the user can march through the field quite readily with gauge in one hand and stand in the other. An added advantage of the stands is that the user can operate the gauge while standing, avoiding the back strain incurred when the gauge is set directly on top of the access tube.

5) Ensure that standard counts are not influenced by soil water content. This is another advantage of the stands. We set up the stand on a base plate to take standard counts in the field away from vegetation. Previous to this we saw that standard counts varied depending on whether the soil was sopping wet from a heavy rain or dry (this with the gauge case set on the soil surface and the gauge set on the case for the standard count).

Madera probes and accessories may be purchased from

Precision Machine Company, Inc.
2933 North 36th Street
Lincoln, NE 68504-2498

402.467.5528
FAX: 402.467.5530

They have probes for different soil types. Basically these offer thicker or thinner walls depending on soil resistance. Their "heavy clay" probe has the thickest walls I believe. We use the "clay" probes. We haven't used the driver from PMCI. We just use a block of fir against the top of the probe and a 1 ½ lb hammer to drive with. This probe works well because of the small cross sectional area normal to the axis of insertion, and the reamed body behind the cutting bit (Fig. 1), which relieves the core from frictional forces as it moves through the body of the probe. The bayonet mount ears on the top of the probe provide an ideal place to insert a rod to use to twist the probe before pulling it out of the soil. The twisting action shears the soil at the front end

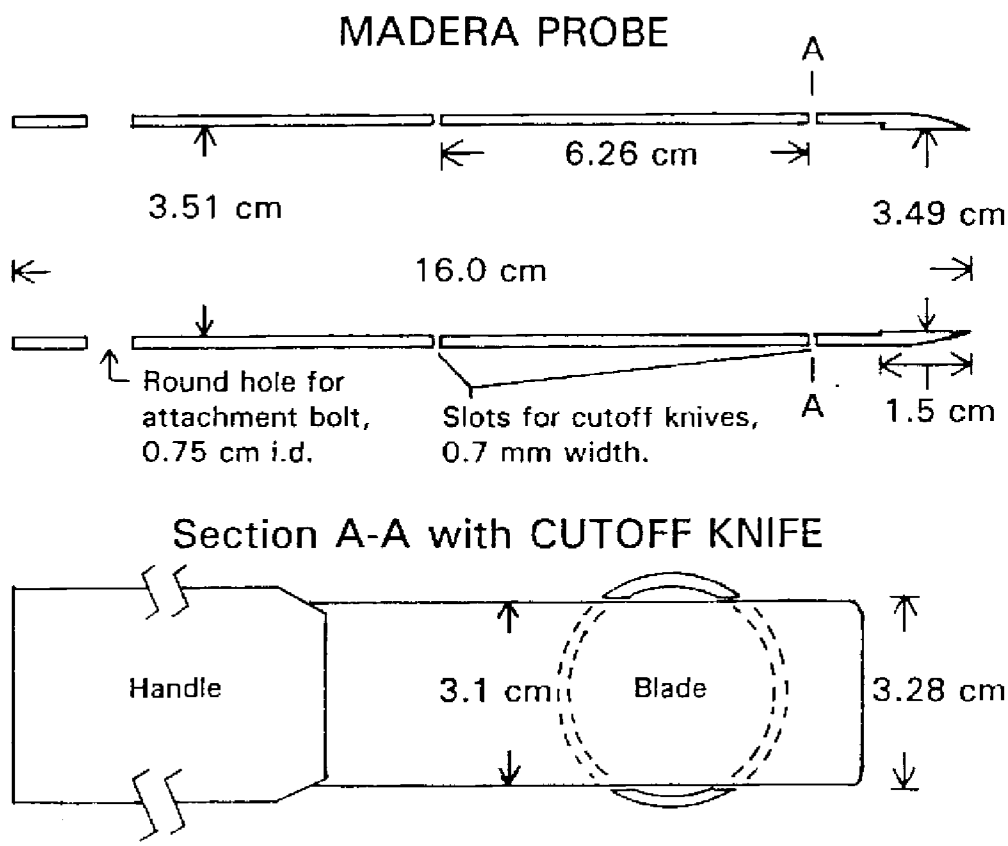

Figure 1. Madera probe schematic.

of the probe. We've found that lubricating the probe with silicone spray reduces compaction in some soils. Most of the lubricant is pushed off the probe by the first soil that passes through it so that negligible lubricant finds its way into the sample.

These probes have two slots for cutting the sample to produce the 60 cm^3 volumetric sample.   Spatulas as sold by VWR, Cole-Parmer, PGC Scientifics, etc. will insert easily into these slots. One can do the same thing with spatulas sold in hardware stores, though most of these are too wide and must be ground to the right width on a bench grinder.

Temperature Affects Standard Counts

Figure 2 shows data measured in 1985 using a Campbell Pacific Nuclear 503DR gauge during a field calibration exercise at Marana, Arizona. The calibration required the manual installation of access tubes and extraction of soil samples at several depths as the hole was augered. This was quite time consuming and installation of a particular access tube could finish at any time of the day. Just before taking count readings at the various depths in the access tube I took a standard count in the shield and recorded the mean count, Chi ratio and time. The gauge was in the field during the entire time and was equilibrated to air temperature as much as possible. I had a weather station in the field and was recording air temperature every 15 minutes. I used the nearest 15 minute average air temperature and standard counts for which Chi ratios were above 0.9 and below 1.1 to build the data set that is shown in the graph.

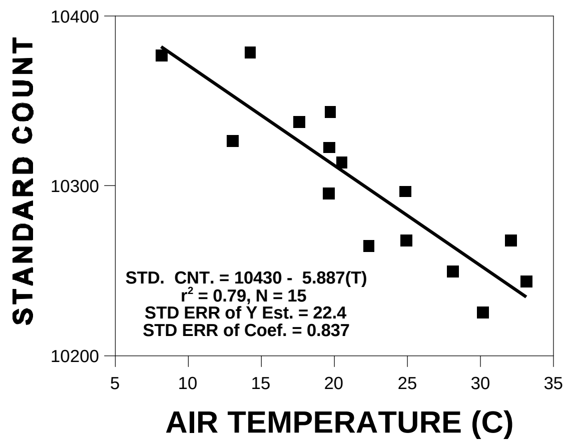

Figure 2. Standard counts from Campbell Pacific Nuclear (Martinez, CA) model 503DR neutron moisture gauge and corresponding ambient temperatures at Marana, AZ, 1985.

Linear regression (see Fig. 1) shows that the ambient temperature explains 79% of the variation in standard count. The correlation is negative with lower standard counts for higher temperatures. For a temperature change of 30 °C we could expect a change in standard count of 177. The calibration equation for this probe had a slope of 3.59×10^{-5}. Multiplying the slope by the change in standard count gives a change in measured water content of 0.006 $m^3\ m^{-3}$. This is close enough to a 1% change in water content to cause some concern.

There are some reasons to expect that the primary source of temperature dependency is the detector tube which contains boron trifluoride gas. Gas pressure is quite responsive to temperature changes and I assume that the detection process is influenced by gas pressure. The counting circuitry may also be involved but I would think that, except for the detector circuit which is somewhat analog in nature, the circuitry in the probe would be insensitive to temperature because it is basically digital. Certainly the electronics in the gauge readout assembly, where the microcontroller is housed, are entirely digital so the problem almost certainly resides in the probe.

In our semiarid environment we often see a 30 °C air temperature swing during the working day. There is some potential for the probe to be subjected to even wider temperature swings because it is used in the access tube, as well as in the shield for standard counts. We don't have any idea what temperature the probe is at while it is in the access tube but we can be sure that it is changing. While traveling from one access tube to another the probe is locked in the shield and may equilibrate with ambient temperature. Once the probe is lowered to the bottom of the access tube it enters a much cooler or warmer environment depending on air temperature. As the probe is moved to each new depth stop for a reading it enters another temperature regime. Because we don't have a measure of probe or detector tube temperature we can't really correct for temperature swings. We can measure the effect as I did from standard counts in the field or using an environmental housing set to different temperatures for each standard count but that information is useless to us unless we can measure the probe temperature during each reading in the access tube and during each routine standard count in the field.